[0039] Varying the frequency of the control signal applied to the backplane, and/or the control electrode can cause a variation in the frequency at which a piezoelectric actuator expands and contracts. Varying the amplitude of the control signal applied to the control electrode can vary the amount by which the piezoelectric material expands, which the user may feel as an increase or decrease in the strength of the vibration.

[0040] In some embodiments, the waveform of the control signals, the frequency of the control signals, and/or the amplitude of the control signals can be adjusted by the user.

[0041] In some embodiments, the present invention can be integrated with a speaker to provide audible sounds to a user. Control signals can also be applied to electrodes, such as electrodes **102** and **104** of FIG. **1**, to generate vibrations in the audible range. This may cause the piezoelectric actuator to emit an audible signal.

[0042] FIG. **4** shows exemplary electronic device **400**, which is in accordance with the principles of the present invention and includes touchscreen input component **402**. Electronic device **400** can function as, for example, a media device, communications device, digital camera, video camera, storage device, or any other electronic device.

[0043] Touchscreen input component **402** includes a surface capable of providing dynamic localized haptic feedback. For example, touchscreen input component **402** can include a number of actuators, which are shown in a planar configuration as a grid of transparent piezoelectric actuators. Exploded view **404** shows the individual actuators. Although half of the actuators are shown in exploded view **404** as being shaded, one skilled in the art will appreciate that all of the actuators can be transparent, or in other embodiments opaque, or a combination thereof. Exploded view **404** also depicts the individual piezoelectric actuators as being arranged in a grid comprising rows and columns, such as those discussed above.

[0044] FIG. **5** shows cross-section **500**, which includes an exemplary grid of piezoelectric actuators, overlaying a touchscreen input component such as, e.g., touchscreen input component **402** of FIG. **4**. Transparent electrode **504** can be disposed above touchscreen input component **502**. In cross-section **500**, transparent electrode **504** is continuous in the lateral dimension. Transparent electrode **504** can be one of a plurality of electrodes disposed laterally above touchscreen input component **502**, but other transparent electrodes disposed laterally are not visible in this depiction because they run parallel to the view shown in cross-section **500**. Disposed above transparent electrode **504** is transparent piezoelectric material **506**. Cross-section **500** shows, transparent electrodes **508**, **510**, **512**, **514**, and **516** as being disposed above transparent piezoelectric material **506**. Transparent electrodes **508**, **510**, **512**, **514**, and **516** are disposed orthogonally to transparent electrode **508**. Although the grid of transparent piezoelectric actuators is depicted here above the touchscreen, in other embodiments, the grid of transparent piezoelectric actuators may be disposed behind the touchscreen input component **502** and/or integrated into touchscreen input component **502**.

[0045] FIG. **6** shows electronic device **600**, which is presenting exemplary display **602**. Display **602** includes a number of display elements, such as virtual button **604**, virtual button **606**, empty space **608**, empty space **610** and virtual scroll wheel **612**. Some of the display elements included in display **600**, such as, e.g., virtual buttons **604** and **606** as well as virtual scroll wheel **612** are user-selectable. In response to a touch event occurring in proximity to a user-selectable virtual button (e.g., the user touching a virtual button), electronic device **600** can generate a command and, in response, provide the user a new display with new visual information and display elements, emit one or more audio signals, communicate with another electronic device or server, and/or perform any other function. One skilled in the art will appreciate that the quantity, types, locations, shapes and sizes of user-selectable display elements can change as the display presented by electronic device **600** changes.

[0046] Electronic device **600** can also include a transparent grid of piezoelectric actuators, which cannot be seen by the user and/or does not obstruct the display elements included in display **602**. The grid of piezoelectric actuators can be used to enable each user-selectable display element, the space between each display element (e.g., empty spaces **608** and/or **610**), and/or portions of the display elements to vibrate at unique frequencies and/or amplitudes. For example, virtual buttons **604** and **606** can vibrate at one frequency, while empty spaces **608** and **610** do not vibrate (i.e., remain still). As another example, virtual buttons **604** and **606** can vibrate at the same frequency as empty spaces **608** and **610**, but at different amplitudes. As yet another example, empty spaces **608** and **610** can vibrate while user-selectable display elements remain still.

[0047] In some embodiments of the present invention, to, e.g., conserve battery power, electronic device **600** can only vibrate when a touch event is occurring. In addition, only the portion of display **602** that is being touched can vibrate (if electronic device **600** is configured to do so).

[0048] A display element can also dynamically vibrate to help a user navigate display **602**. For example, empty spaces **608** and **610** can vibrate with an increasing (or decreasing) frequency as a touch event approaches a user-selectable display element (e.g., as the user moves his finger on the touchscreen towards a virtual button). Similarly, the vibrational amplitude can also be dynamic and change as a touch event moves around display **602**. In this manner, electronic device **600** can enable a user to feel display **602** and track, for example, a user's finger and provide localized haptic feedback.

[0049] For example, display **600** can include virtual scroll wheel **612**. Virtual scroll wheel **612** includes two user-selectable display elements, button **614** and wheel **616**. Piezoelectric actuators, located above (or underneath) the touchscreen presenting display **600**, can define the location of virtual scroll wheel **612** by vibrating, while the touchscreen input component simultaneously tracks the user's finger movement. In this manner, electronic device **600** can provide haptic indications of where button **614** and/or wheel **616** are disposed on display **600**. This can enable a user to locate virtual scroll wheel **612** without looking at display **600**. In addition, button **614** and wheel **616** can vibrate at different frequencies and/or amplitudes to enable the user to non-visually distinguish the boundaries of button **614** and wheel **616**. For example, button **614** can vibrate at a higher frequency than wheel **616**, which in turn vibrates at a higher frequency than empty space **620** (which surrounds virtual scroll wheel **612**).

[0050] As another example, a virtual slider, not shown in FIG. **6**, can be included in a display and have haptic feedback characteristics. Piezoelectric actuators, located above (or underneath) the touch-based input component, can imitate physical detents along the slider such as, e.g., the half-way position of a Left-Right slider for mixing audio.